Brookhaven Activities on ATLAS

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for the
DOE Site Visit

September 8, 2009

Outline

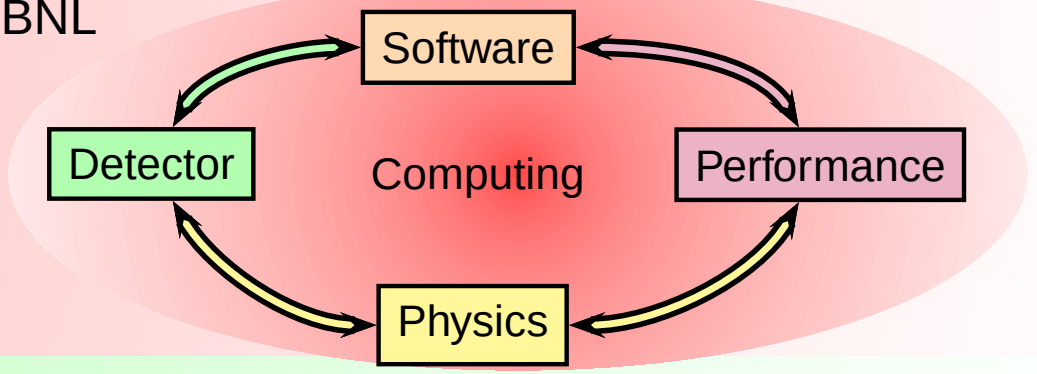
- Detector & Operations
- Software & Performance
- Physics Analyses
- Computing & Support
- Upgrade R&D

Collider Physics at BNL

- BNL is a pioneer in hadron collider physics
  - CERN ISR in 1970's
  - DØ starting in 1980's, Run I and Run II
  - GEM detector design at SSC in early 1990's
  - A major contributor to ATLAS since mid-1990's

ATLAS Authors: 48
second after CERN (128)
8.7% of US, 1.9% of ATLAS
Core (Physicists): 16 FTE
Operations Program: 47 FTE
Other: 5 FTE
US ATLAS host laboratory

- There are strong connections at BNL between physics, detector R&D, software, performance, and physics analysis supported by the computing infrastructure and the theory group



- Essential strategy of the ATLAS program at BNL:

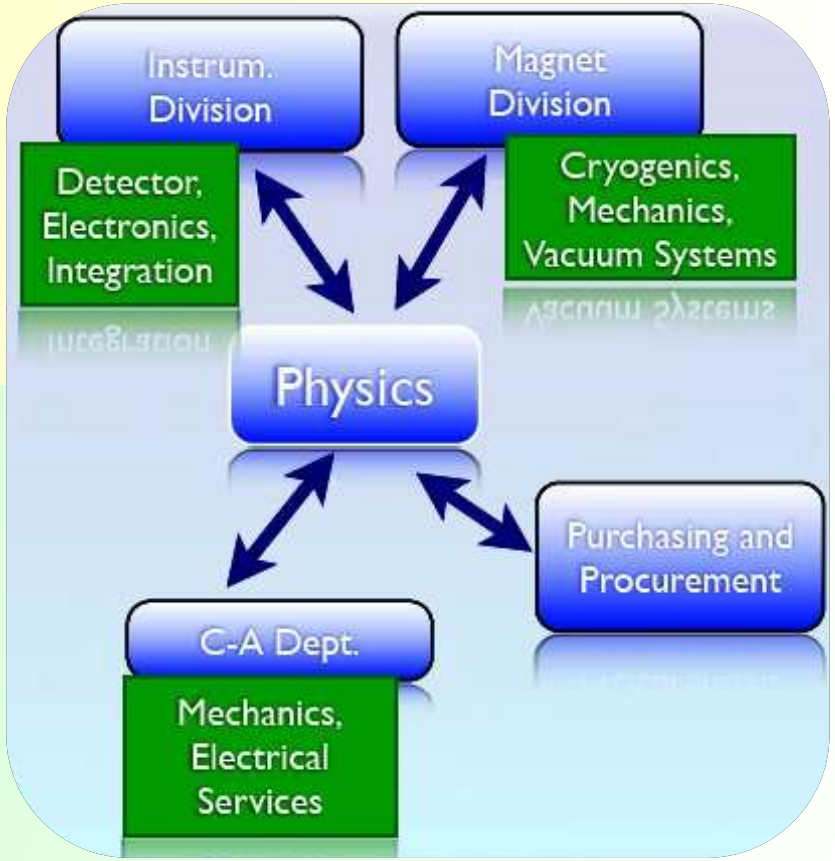
  from detector to software to performance to physics

  - major responsibilities in software & performance match detector & computing expertise guided by physics interests & analysis activities
  - recognized by ATLAS with leadership roles; for example:
    - Muon Cathode Strip Chamber System Manager
    - Deputy Trigger Coordinator
    - 3 of 7 Physics Working Group co-conveners (SUSY, Higgs, Heavy Ion)
    - LAr Upgrade Coordinator

ATLAS Detector Research @ BNL

Success of our participation in the ATLAS experiment has built on:

- Physics:
  - original concepts
  - previous experiments
  - strong theory group
- Unique expertise in detector technology:
  - Liquid Argon Calorimeters
  - Cathode Strip Chambers



- Led to responsibilities during construction and commissioning phase well matched to technical expertise and capability at BNL
  - synergy between laboratory departments and divisions
  - large production capabilities
- Core of scientists coordinates larger technical effort leveraged by:
  - US ATLAS Operations Program
  - BNL Overhead — Instrumentation Division

BNL Contributions to Detector & Operations

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boldface indicates core program funding
indicates Nuclear Physics — not HEP funded

Major responsibilities in detector construction, operation, and in technical coordination

Cathode Strip Chambers

CSC System Manager: ***Polychronakos***
Farrell, Gordeev, Gratchev, Ikarios, Junnarkar, Kandasamy, Muller, Nikolopoulos, O'Connor, **Polychronakos**, Tcherniatine

Technical Coordination

TC Project Office: ***Lissauer*** *(2001–9)*
Duffin, Farrell, Gordeev, **Lissauer**, **Polychronakos**, Stumer

Trigger

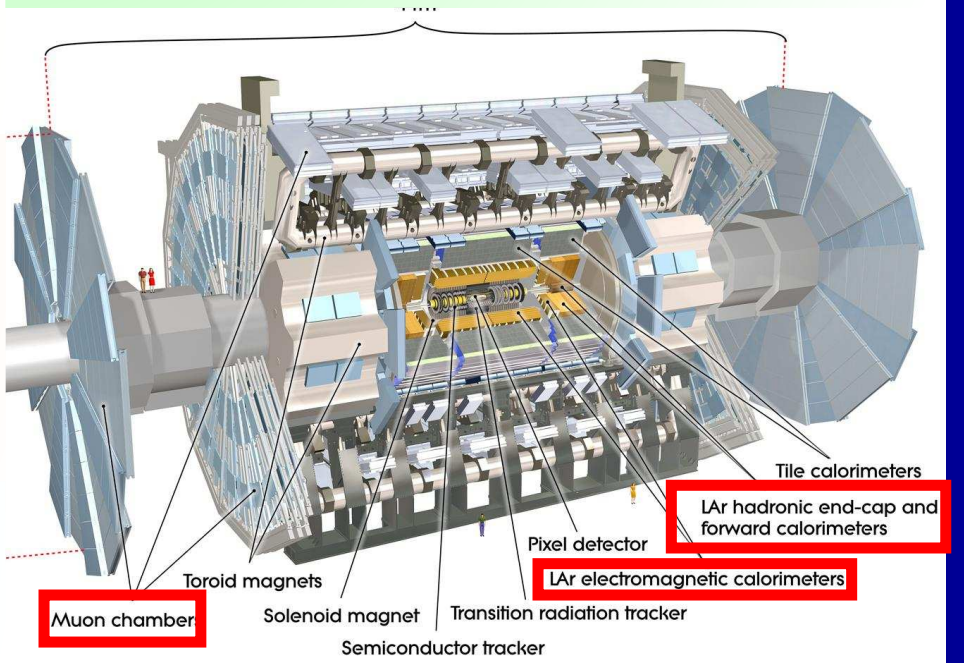
Deputy Trigger Coordinator: ***Rajagopalan*** *(2009–)*
Trigger Menu Coordinator: ***Rajagopalan***
LAr High Level Trigger Co-Convenor: Damazio

Zero Degree Calorimeter

System Manager: *White*
Steinberg, White

Liquid Argon Calorimeter

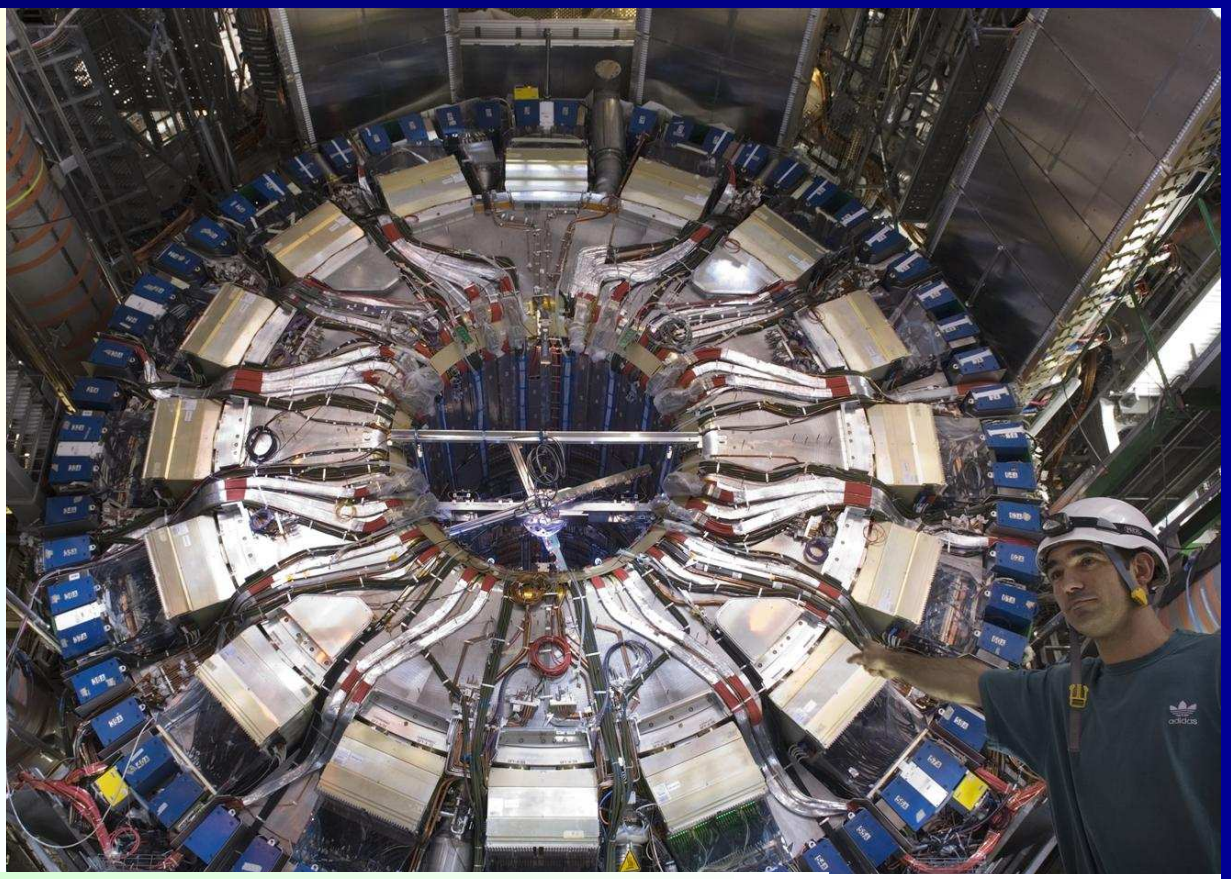
LAr Steering Group: ***Lanni, Ma***
Chen, Damazio, Duffin, **Hackenburg**, Kierstead, **Lanni**, **Lissauer**, **Ma**, **Majewski**, Makowiecki, Muller, Radeka, **Rahm**, **Rajagopalan**, Rescia, Sondericker, **Tarrade**, **Takai**



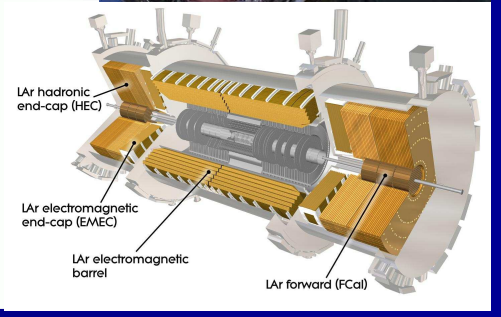
some names only present for historical purposes

Liquid Argon Calorimeters

- BNL has responsibilites in:
  - Cryostat & Cryogenics
  - Cold Electronics
  - Feedthroughs
  - Pedestals, Baseplanes
  - Preamplifiers
  - Low Voltage Power Supplies (LVPS)
  - Detector/Readout Integration
- Status:
  - Installation completed in 2007
  - Currently being commissioned with cosmic-ray muons



- Operations Plans:
  - Front-End electronics integration
  - Develop backup options for long-term LVPS reliability
  - Calibrations & Performance
  - Remote monitoring LAr status from BNL

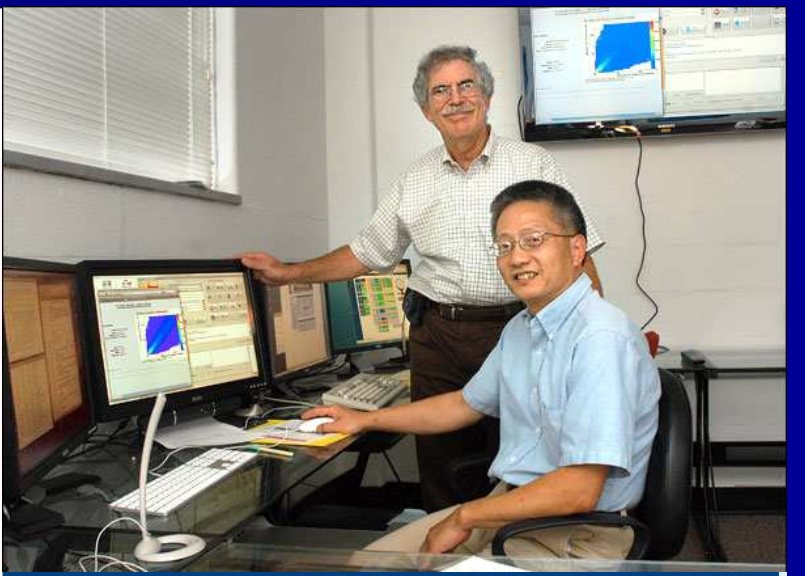


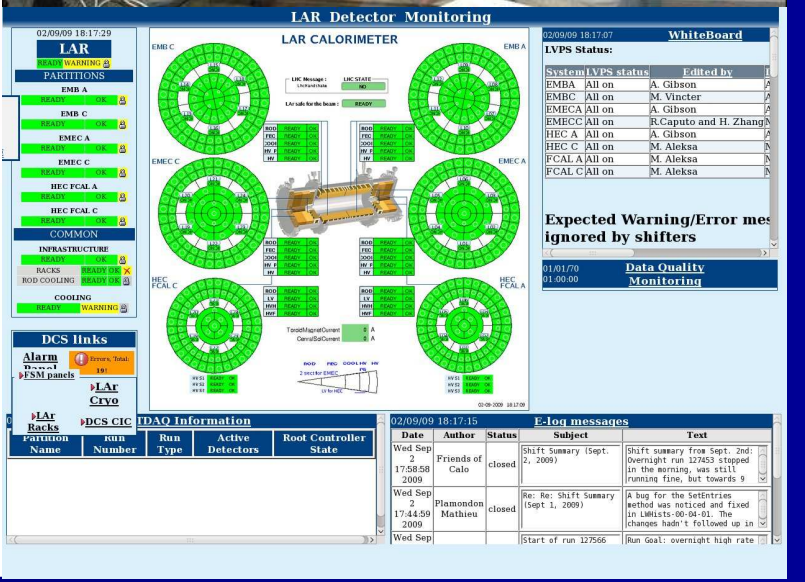
LAr Remote Monitoring

BNL plans to remotely monitor the status of the LAr during data-taking operations:

- Monitor detector status and analyze data dynamically
  - same infrastucture and interfaces as at P1
- Improve data quality by including collaborators not resident at CERN
  - leverage BNL expertise
- Conditions:
  - monitor without impacting operations
  - no control functions outside P1

- Remote monitoring shifts
  (convenient time zone for night shifts)
  - tested during software exercises and cosmic-ray data taking
  - **Begel**, Chen, **Gordon**, **Ma**, **Majewski**, **Snyder**





Cathode Strip Chambers for Forward Muon Spectrometer

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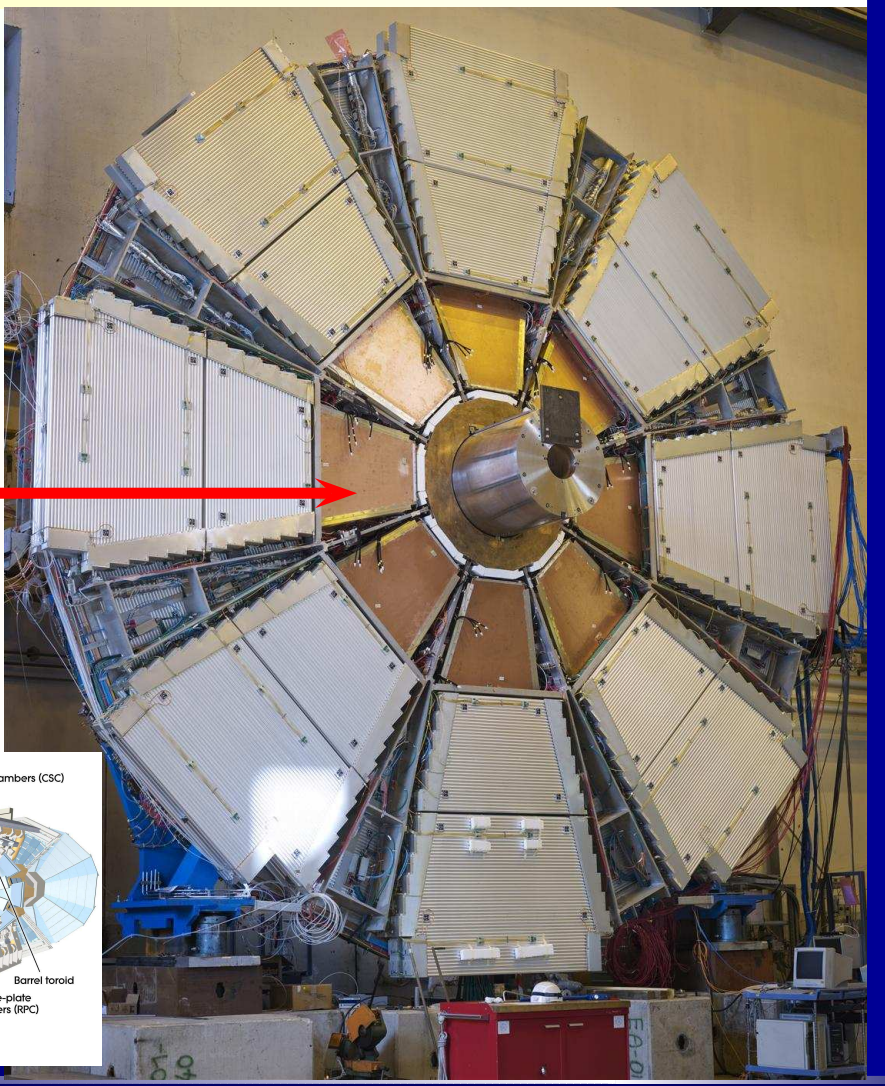
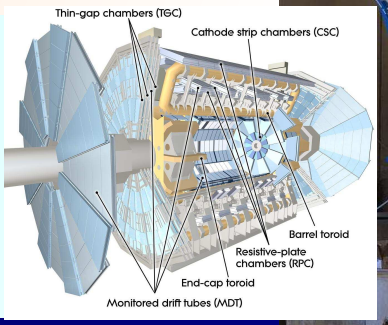
BNL developed the technology originally for E814 and then for GEM @ SSC. Phenix @ RHIC and all LHC experiments use detectors based on concept.

- BNL has primary responsibility for CSC
  - overall management
  - design, construction, validation, installation
  - on-detector electronics
  - service installation and maintenance

- Status:
  - installation of chamber on Small Wheel completed Oct 2007
  - lowered into pit and installed by Mar 2008
  - currently being commissioned with cosmic-ray muons

- Operations Plans:
  - maintenance of overall system
  - data analysis for performance optimization

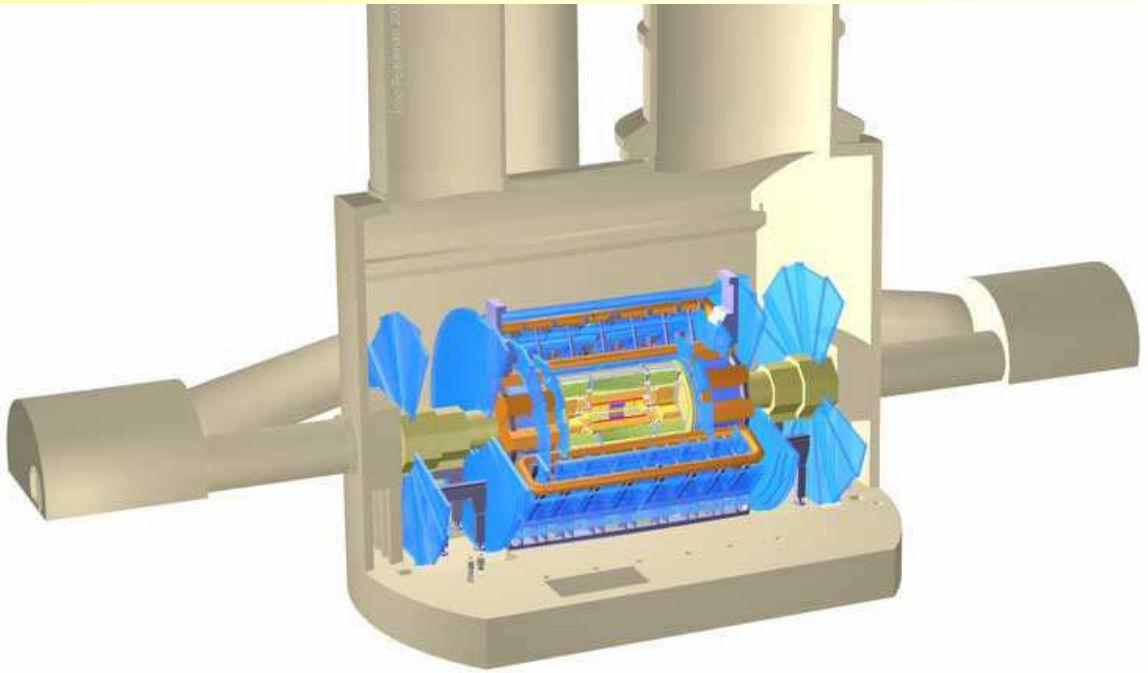




Technical Coordination

Brookhaven played an important role in Technical Coordination:

- Project Management
- Configuration Control
- Floor Stability Monitoring
- Access/Installation Tooling
- Component Placement Strategy and Survey
- Pixel Installation Beam Pipe



- **Lissauer**
  - TC Project Office Head (2001–9)
  - ATLAS Technical Management Board
  - ATLAS Upgrade Project Office Head
  - US ATLAS Technical Coordination Manager

  Lissauer left for NSF in February 2009
- **Polychronakos**
  - US ATLAS Technical Coordination Manager
  - liasion between BNL technical personnel and ATLAS TC
- We will continue to support US engineering activities

BNL Contributions to Software & Performance

boldface indicates core program funding
indicates Nuclear Physics — not HEP funded

Major responsibilities in software/performance well matched to our detector projects and software expertise

Liquid Argon Calorimeter

Commissioning Analysis Coor: ***Ma*** *(2006–7)*
Software & Performance Coor: ***Ma*** *(2007–)*
Ma, **Majewski**, **Rajagopalan**, **Snyder**, **Tarrade**

Muon Spectrometer

Adams, **Assamagan**

Trigger

Menu Coordinator: ***Rajagopalan***
SUSY Trigger Coordinator: ***Redlinger***
LAr High Level Trigger Co-Convenor: Damazio
Begel, Damazio, **Redlinger**, **Rajagopalan**

ZDC

Baker, Steinberg

Core Architecture

Assamagan, **Ma**, **Rajagopalan**, **Snyder**

Physics Analysis Tools

Coordinator: ***Assamagan*** *(2004–7)*
Assamagan, Mete, **Pleier**, **Protopopescu**, **Snyder**

e–gamma

US ATLAS co-convener: ***Snyder***
Ma, **Rajagopalan**, **Snyder**,
Baker, Jia

Jets and $\not{E}_T$

Begel, **Majewski**, **Paige**, **Pleier**

Muons

Adams, **Assamagan**

Taus

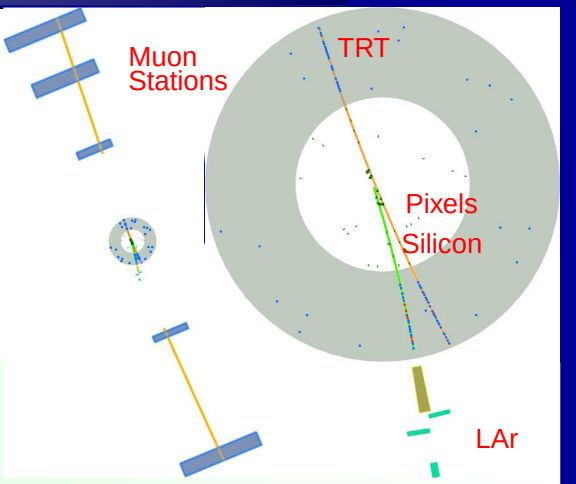
Protopopescu, **Patwa**, **Tarrade**

Tracking

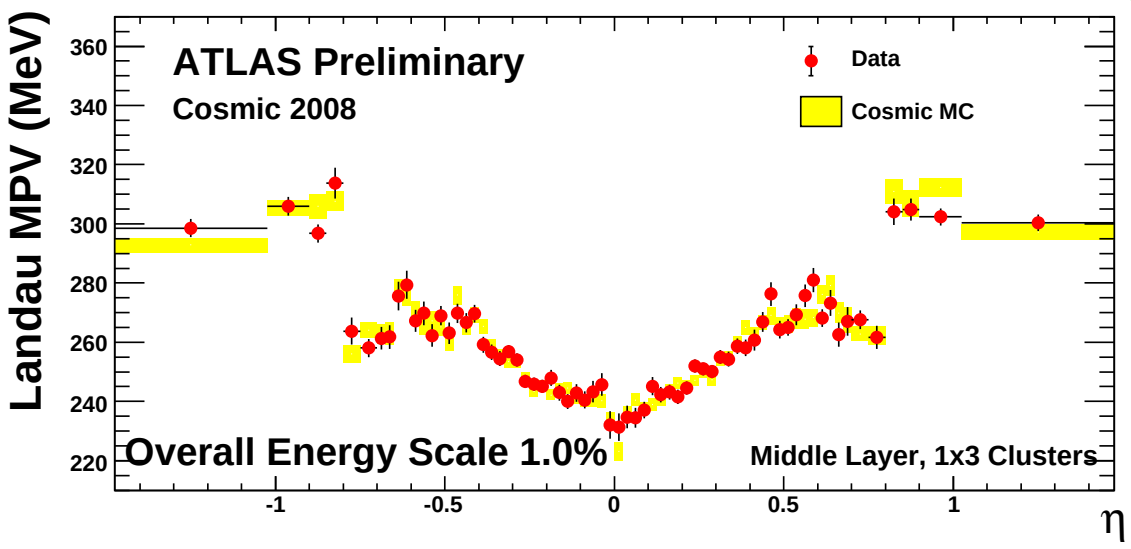
Debbe, Steinberg

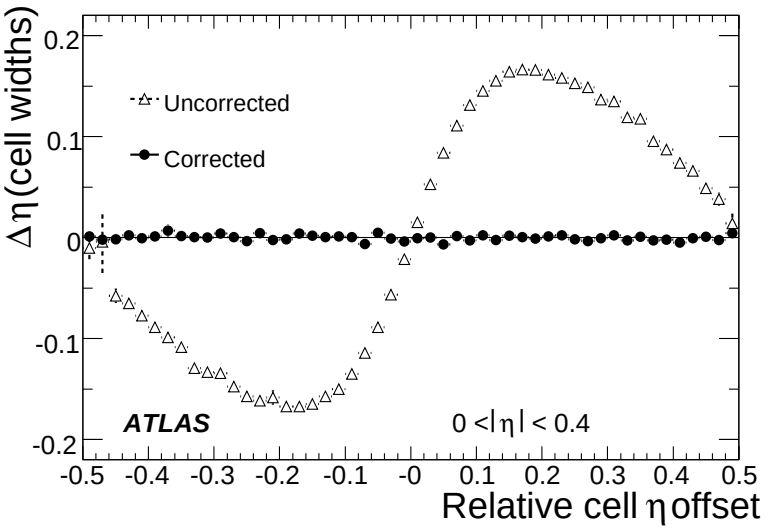
LAr Commissioning & e–gamma

- BNL's strong involvement in LAr calorimeter led to software development and calibration of EM calorimeter
  - automated electronics calibration process
  - timing understood at 2 ns level from splash events
  - muon response uniformity $<$ 1% using cosmic-ray muons



- Developed initial software for identifying EM clusters, the basis of electrons and photons
- Derived position corrections for EM clusters (based on MC)
- In situ calibration using e^+e^- from Z and J/ψ decays (with SUNY Stony Brook)



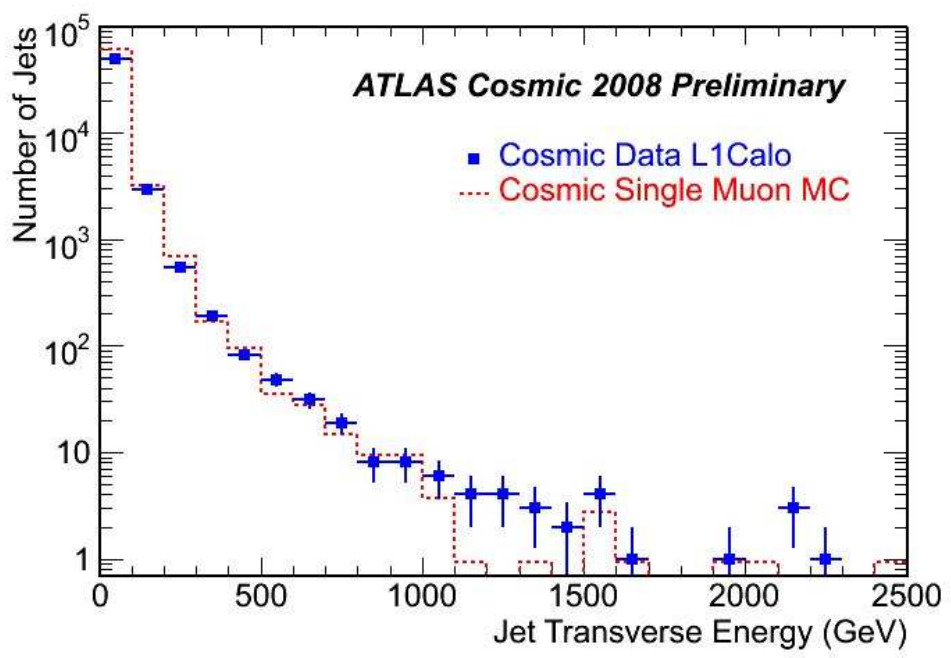


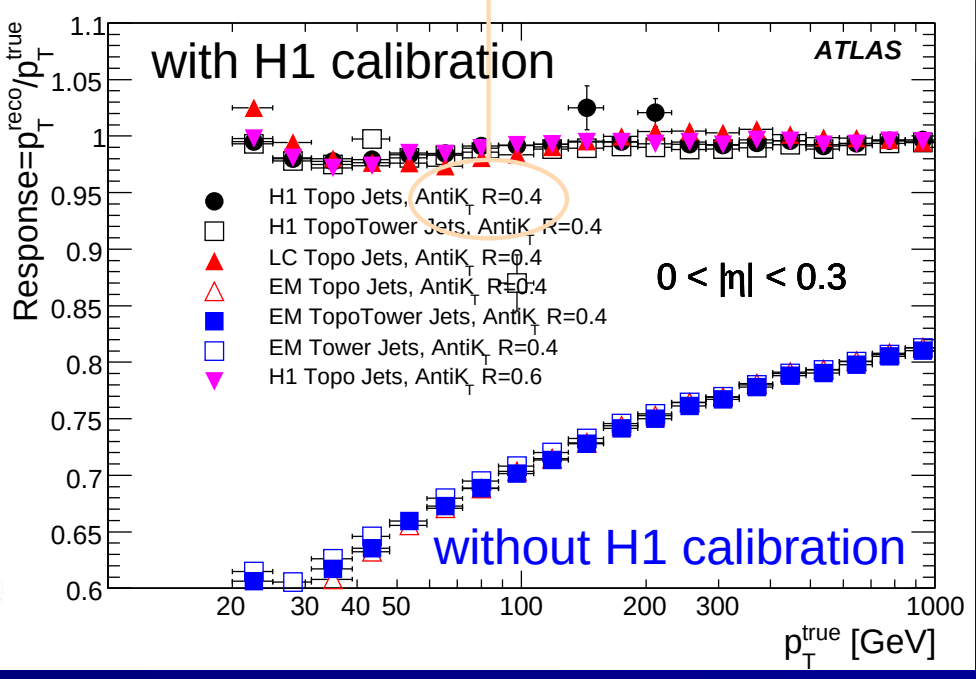
Jet Performance

BNL's physics interests and our expertise in calorimetry led to involvement in the understanding of jets at ATLAS

- Developed cell-based hadronic calibration weighting scheme, aka, "H1 weighting"
  - **default jet calibration in ATLAS**
- Understanding jet energy calibration through photon–jet balance
- Measuring calorimeter jet performance with jets made from tracks (in collaboration with SLAC)

ATLAS has chosen the anti-k_T jet algorithm for most analyses. Soyez, a BNL theorist, co-developed the algorithm.

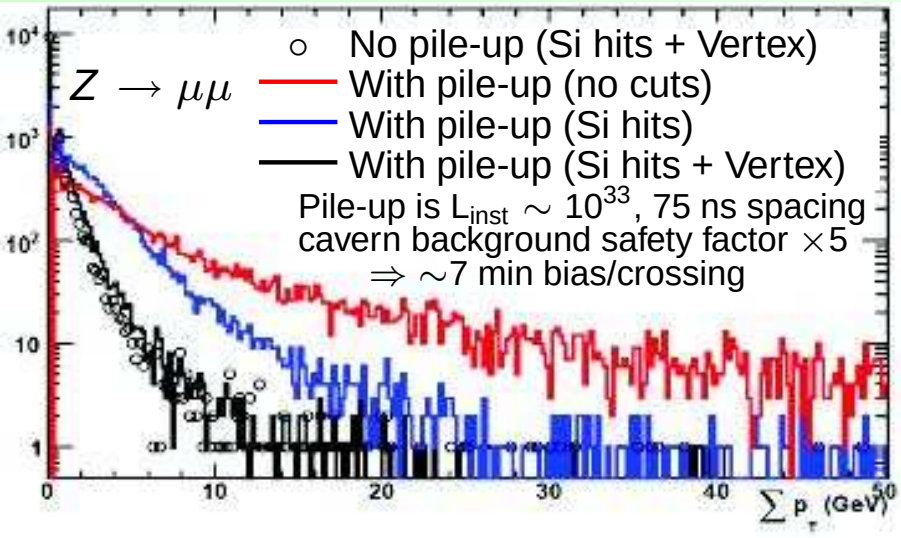


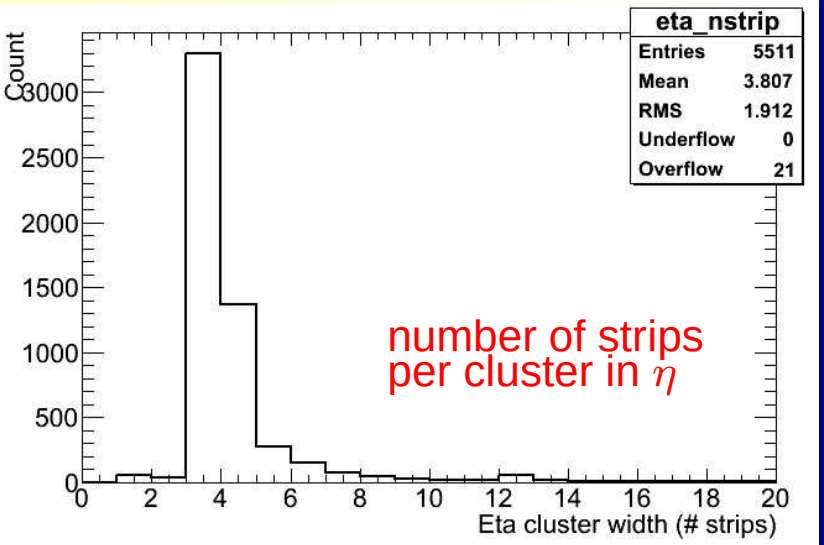


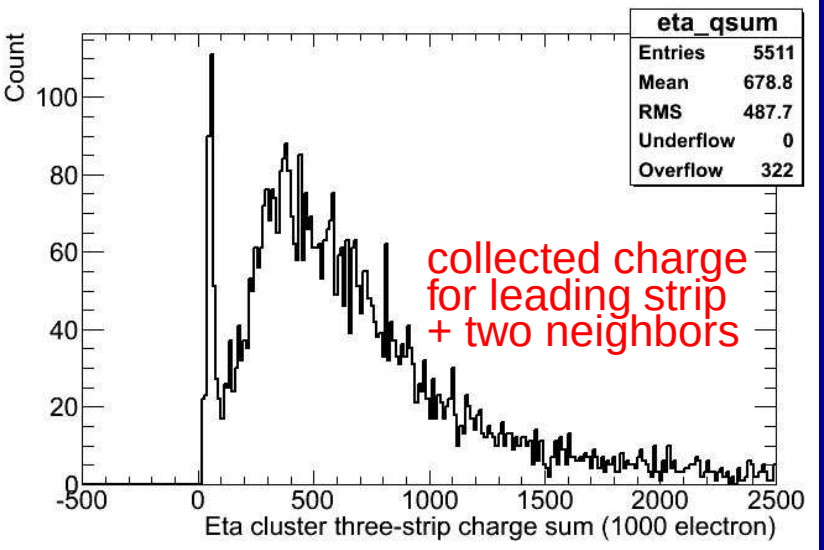
Muon Performance

Our physics interests and expertise led to investment in muon software & performance

- Software development and maintenance
  - CSC detector
  - simulation for cavern backgrounds
  - muon reconstruction, selection, and validation
  - isolation tools
- Characterization of muon performance
- Study impact of pileup on isolation
  (**Assamagan** responsible for core software
  to overlay events for pileup studies)
- Rate studies of cavern backgrounds





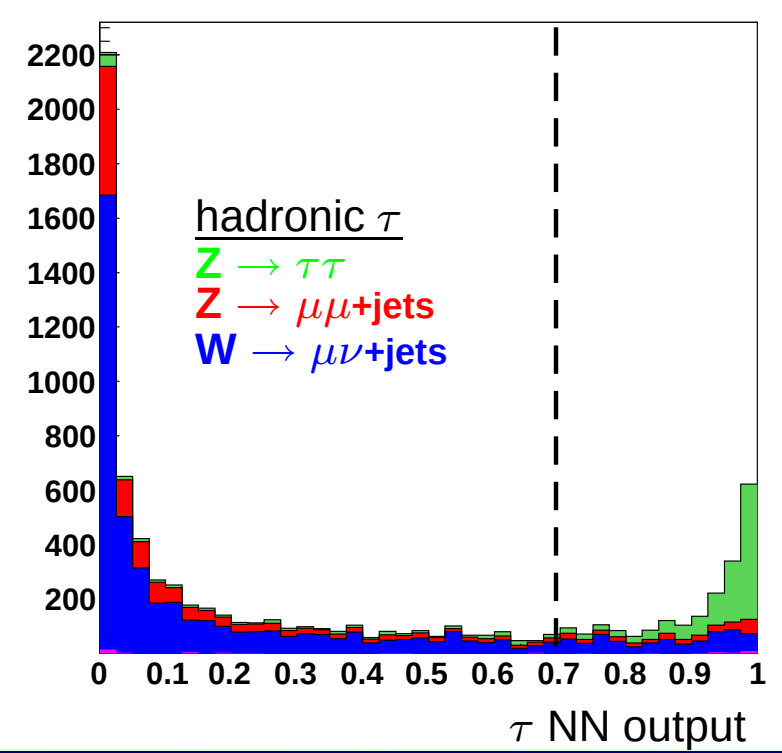


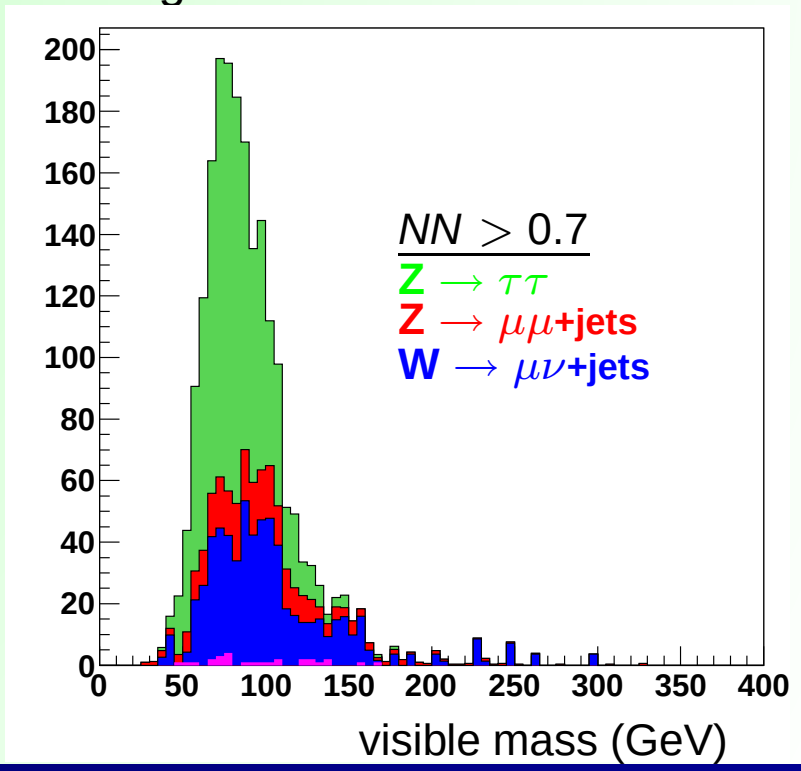
Tau Performance

We developed significant expertise in tau identification and physics on DØ. Now migrating to ATLAS.

- Hadronic τ identification relies on multi-variate analysis techniques to separate real τ leptons from jets, electrons, and muons

- BNL has contributed to core software, validation, and selection criteria
- Studied selections for $Z \rightarrow \tau\tau$ and $t\bar{t} \rightarrow \tau\ell$+jets
- Preparing for measurement of QCD multijet backgrounds





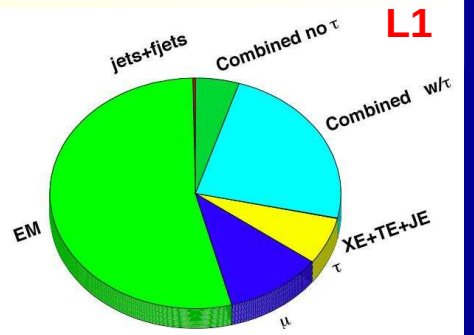
Trigger

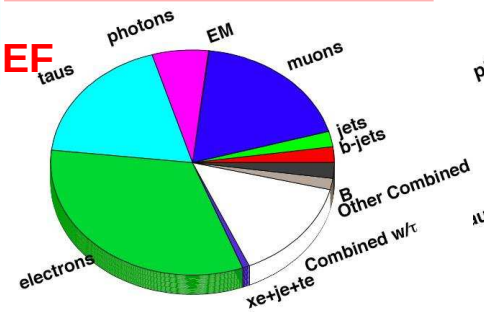
- **Rajagopalan** coordinates the Trigger Menu effort: understanding the trigger rates, balancing performance/physics needs

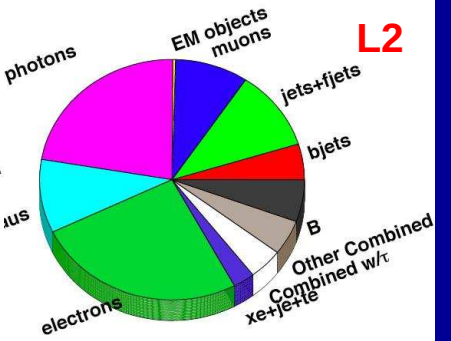
- High Level Trigger (L2 & Event Filter) infrastructure and timing
- Re-designed and implemented the primary offline interface between the user and trigger information
  (in collaboration with DESY & UC Irvine)

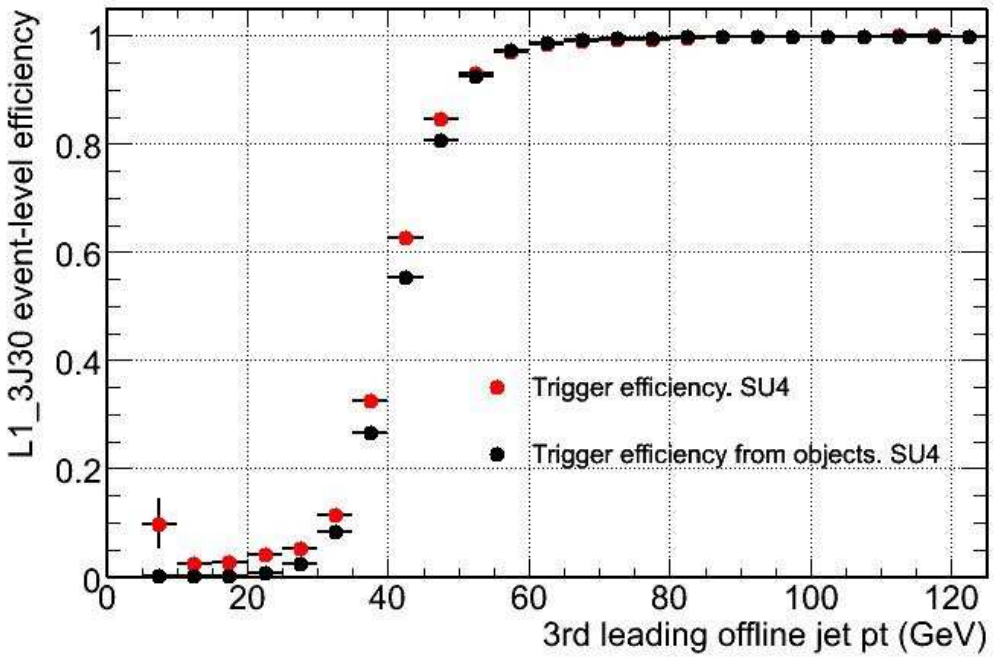
$L_{inst} \sim 10^{31}$

L1	6470 Hz
L2	427 Hz
EF	95 Hz





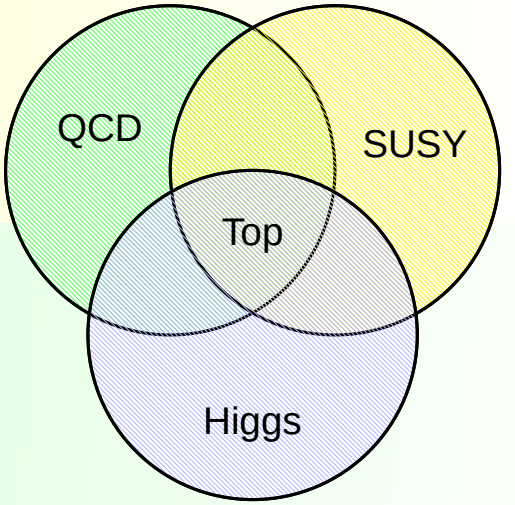




- Trigger Studies:
  - multijet trigger efficiency studies
  - new jet triggers for SUSY background control samples
  - new jet triggers for SUSY searches in dijet+$\not{E}_T$ channel ($\tilde{q}_R \rightarrow q\chi_1^0$)

BNL Physics Analysis on ATLAS

- BNL has built a strong foundation for physics analysis
  - extensive expertise in detector, software, and performance
  - lead analysis software tool development
  - active in physics analysis since the beginning of ATLAS



- Leadership roles as ATLAS Physics Group Co-Conveners
  - Higgs: **Assamagan** (2008–10)
  - SUSY: **Redlinger** (2009–11)
  - Heavy Ions: Steinberg (2008–10)
- Our current focus is on preparation for the initial running
  - Standard Model physics
  - backgrounds to signatures of new physics
  - staff each analysis with at least one leading scientist, $1-2$ post-docs and/or students
  - requires increasing the number of postdocs for analysis
  - agreement with Iowa State U. & U. Oregon to share support for students
  - BNL physicists hold advisory role for students
- Our long-term interests are in searches for new physical phenomena
- Productive collaborations with BNL theorists

- LHC run in 2009–10
  - $\sqrt{s} = 7-10$ TeV and $L_{inst} \sim 10^{32} \Rightarrow$ 4 interactions/crossing for $\int L = \mathcal{O}(100)\,\text{pb}^{-1}$

QCD Physics

Minimum Bias Physics

Steinberg

physics with extremely early data [$\mathcal{O}(1)\,\mu\mathrm{b}^{-1}$]

Dijet Azimuthal Decorrelations

Begel, **Majewski**, **Paige**

precision test of pQCD with early data and initial jet energy scale [$\mathcal{O}(1)\,\mathrm{pb}^{-1}$]

$\mathrm{d}\sigma/\mathrm{d}p_T$ for $Z/\gamma^\star \to \mu^+\mu^-$

Adams, **Begel**, Yamamoto

study initial-state radiation [$\mathcal{O}(20)\,\mathrm{pb}^{-1}$]

Inclusive μ, $\mu\mu$, multi-μ Spectrum

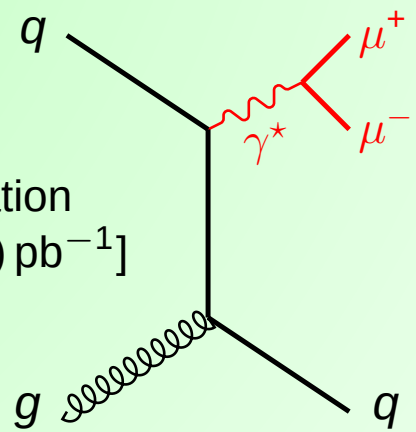
Adams, **Redlinger**

test detector and Monte Carlo in early data

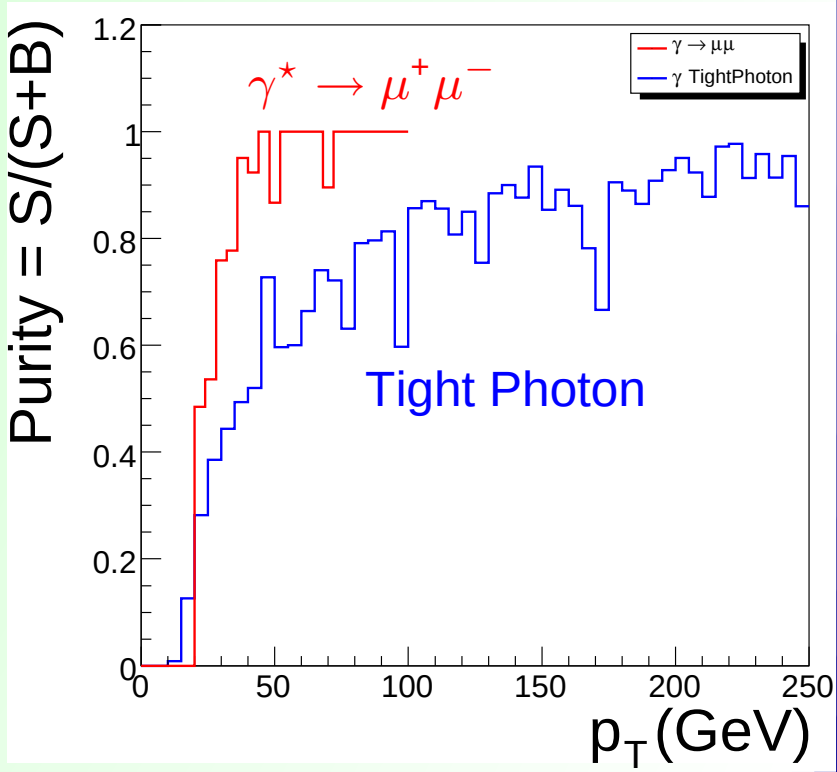
Direct Photon Production via $\gamma^\star \to \mu^+\mu^-$

Adams, **Begel**, **Paige**

- High p_T low-mass Drell-Yan $\mu^+\mu^-$ production
- Background samples are interesting ($\mathcal{O}(10)\,\mathrm{pb}^{-1}$)
  - heavy-flavor and J/ψ production
  - J/ψ+jet useful for low p_T jet energy scale calibration
  - J/ψ is extremely clean b tag ($B \to J/\psi \to \mu^+\mu^-$)
- $\gamma^\star$+jet provides clean calibration signal for low p_T jets [$\mathcal{O}(100)\,\mathrm{pb}^{-1}$]



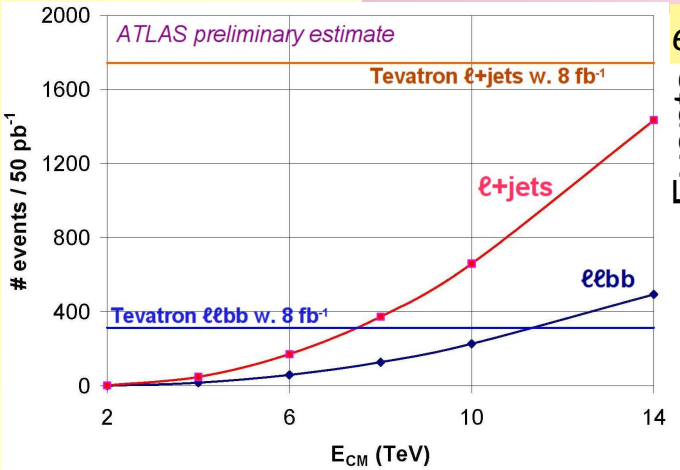
connection with **Kilgore** from BNL HEP Theory Group

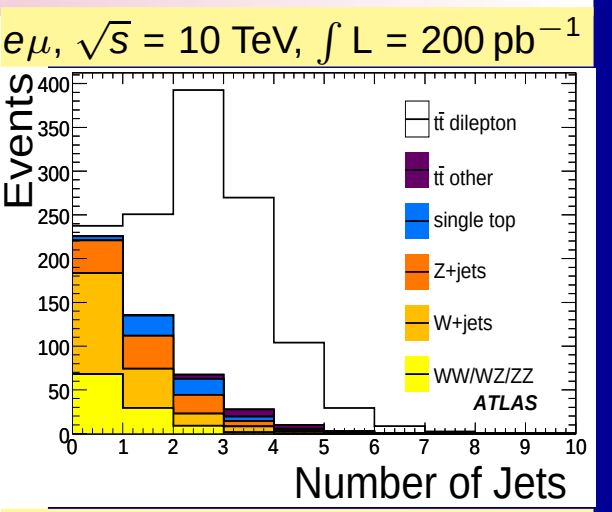


Top Physics

Begel, **Gadfort**, Mete, **Pleier**, **Protopopescu**, **Rajagopalan**, Searcy

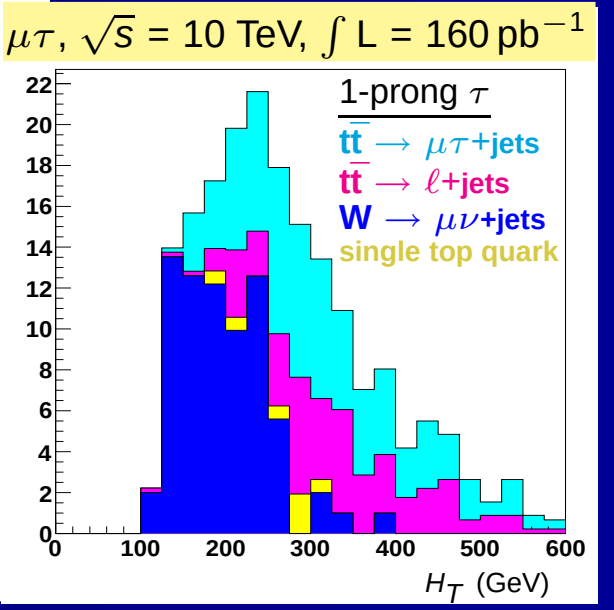
- The LHC is a top factory!
  - likely to see signatures of new physics
  - significant background to new physics (e.g., SUSY)
  - BNL very experienced in top physics from our DØ efforts





- BNL concentrating on $t\bar{t}$ production in dilepton decay channel
  - $e\mu$, ee, $\mu\mu$
    in collaboration with Bonn, U. Glasgow, UC Irvine, New York U., U. Oregon, Toronto, Stockholm, Yale
  - leverage our experience in hadronic τ decays
    - lepton + hadronic τ
    - lepton + isolated track

    increases sensitivity to new physics such as charged Higgs boson



Search for Supersymmetry

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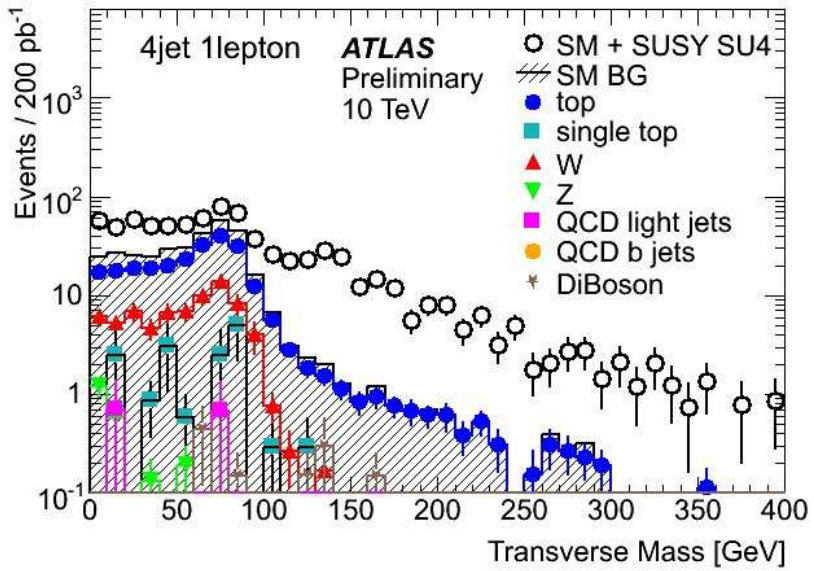
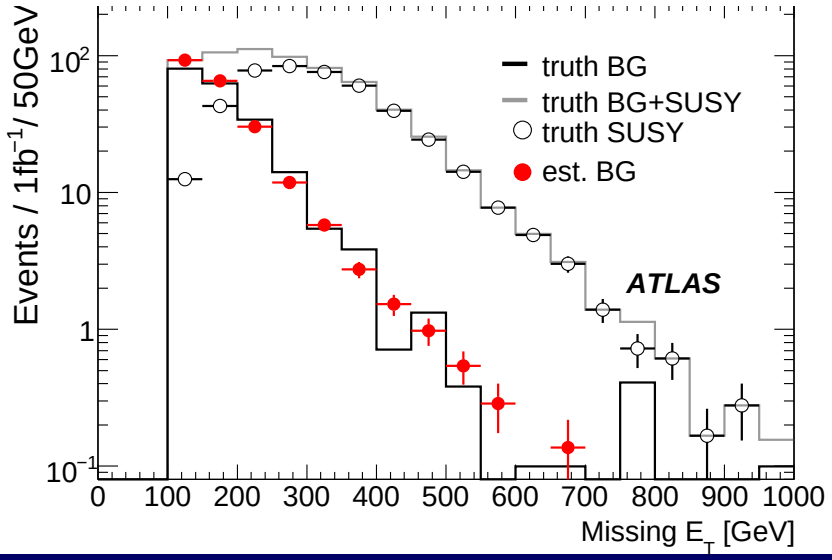
SUSY Group Co-Convener: ***Redlinger***
Begel, **Majewski**, **Gibbard**, **Paige**, **Redlinger**

- The search for SUSY has been a focus of the BNL group since the earliest days of ATLAS

- Concentrate on the ℓ+jets+ $\not\!\!E_T$ channel
  - good reach prospects
  - better controlled background systematics
- Study data-driven methods to determine backgrounds:
  - $t\bar{t}$ in dilepton and ℓ+jets decay channels (ℓ+jets in collaboration with Indiana U.)
  - use γ+jets to estimate W+jets background
  - QCD multijet
- Extend QCD dijet azimuthal angle measurement to increase SUSY sensitivity

- Exploring collaboration with BNL theory group on V+jets production
  - understanding sources of theoretical uncertainties





Search for the Higgs Boson

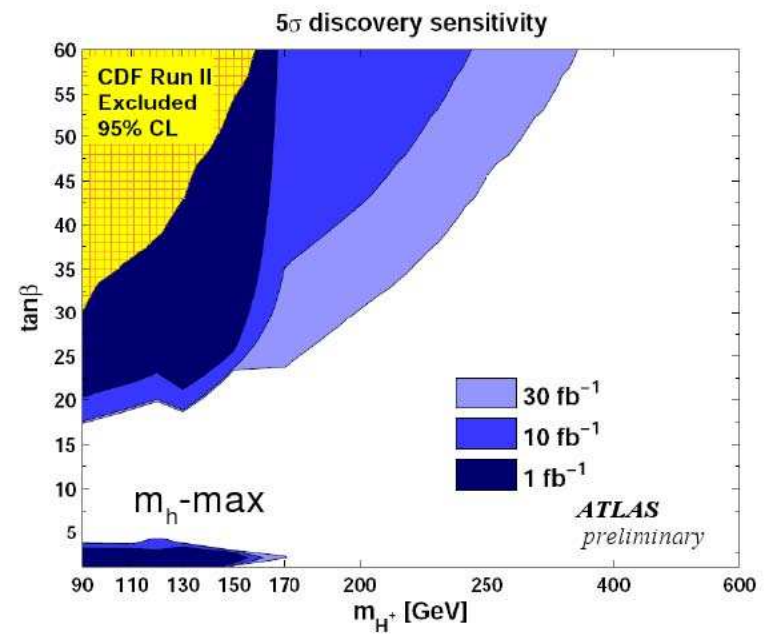
BROOKHAVEN NATIONAL LABORATORY

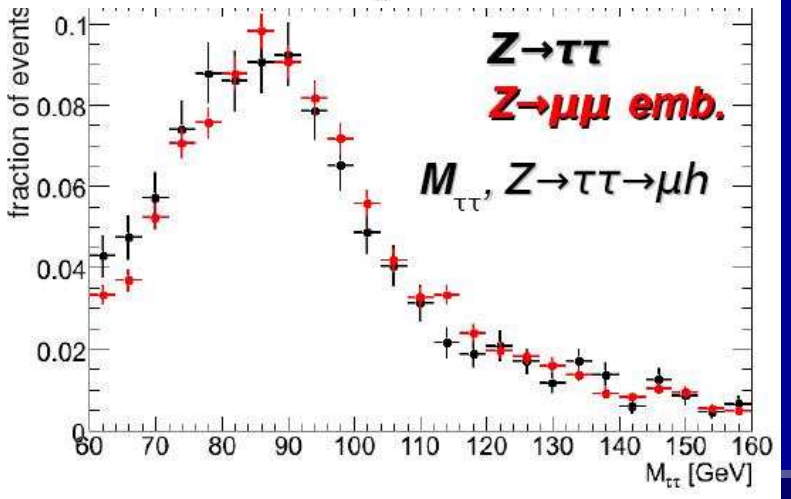
Higgs Group Co-Convener: ***Assamagan***
Assamagan, **Pleier**, **Protopopescu**, **Tarrade**

- The search for the Higgs Boson is a focus of our long-term plans for physics at ATLAS

- $H^{\pm} \rightarrow \chi^{\pm}\chi^{0} \rightarrow \ell\ell\ell + \not{E}_T$ +jets
  - sensitivity with $\mathcal{O}(200)\,\text{pb}^{-1}$ at $\sqrt{s}$ = 10 TeV
  - collaboration with U. Arizona and Uppsala
  - **Assamagan** supervising a U. Arizona student
- $H \rightarrow ZZ^{\star} \rightarrow \ell\ell\ell\ell$
  - sensitivity with $\mathcal{O}(1)\,\text{fb}^{-1}$ at $\sqrt{s}$ = 14 TeV
  - collaboration with Indiana U., Yale, Johannesburg, ICTP
- $H \rightarrow \tau\tau$
  - $Z \rightarrow \tau\tau$ has same final state and is a significant background
  - studying data-driven background techniques
  - sensitivity with $\mathcal{O}(1)\,\text{fb}^{-1}$ at $\sqrt{s}$ = 14 TeV
  - uses our expertise in τ performance

connections with **Dawson** & **Kilgore** from BNL HEP Theory Group





Analysis Support Center

- BNL is one of the US ATLAS Analysis Support Centers
  - provides US ATLAS physicists with critical mass for collaborating on complex physics analyses
  - utilizes BNL's expertise

- US ATLAS Physics Analysis Jamborees at BNL
  - facilitates interactions between US physicists
  - tutorials, working sessions, US ATLAS Analysis Forum meetings, informal discussions
- Host US ATLAS physicists
  - support university faculty, postdocs, and students
  - extensive access to BNL staff
  - this past year:
    - Columbia U.
    - Iowa State U.
    - UT Arlington
    - UT Dallas
    - U. Oregon

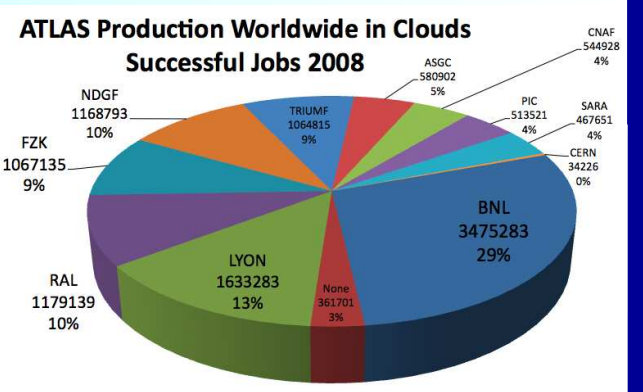
US ATLAS Jamborees at BNL	
Date	Participants
Jun, 2006	30
Aug, 2006	34
Dec, 2006	26
May, 2007	35
Aug, 2007	23
Dec, 2007	53
Mar, 2008	21
Jun, 2008	19
Sep, 2008	38
Dec, 2008	28
Mar, 2009	28
Jun, 2009	26

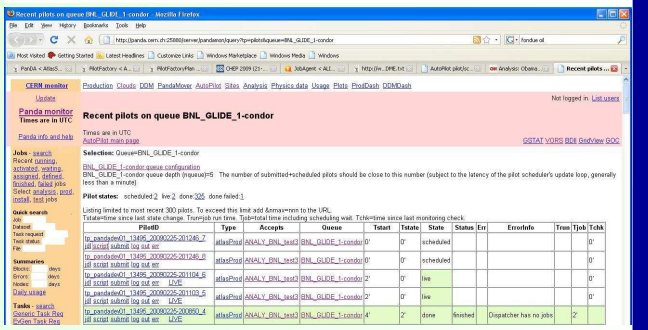
- LHC@BNL Workshops
  - open meeting jointly organized with BNL HEP Theory Group; same week as Jamboree
  - facilitates interactions between experimentalists and theorists; fosters future collaboration
  - current series focuses on early physics at LHC

BNL Computing & Software Applications Support

US ATLAS Facility Manager: Ernst

- Largest and most productive ATLAS Tier 1
  - 3500 job slots; 3.5 PB disk; 3.0 PB tape; 30+ Gbps
  - 20 FTE
- BNL provides significant software applications support:
  - overall responsibility for ATLAS distributed data management & event storage
  - responsible for ATLAS nightly build and test systems
  - principal role developing & managing PanDA — distributed production & analysis system for ATLAS & OSG
    ATLAS has chosen PanDA as its primary tool
  - US ATLAS Software Librarian
- Leadership roles in all focus areas
  - US ATLAS Project: 7.5 FTE software, 1.5 FTE operations
  - Open Science Grid (SciDAC) - 2.5 FTE (0.5 'subcontracted' to UT Arlington)
    OSG Application Area Coordinator: ***Wenaus***
- Most activities shifted from development to operations





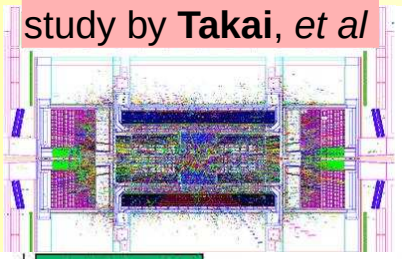
Adams, Searcy, **Wenaus**

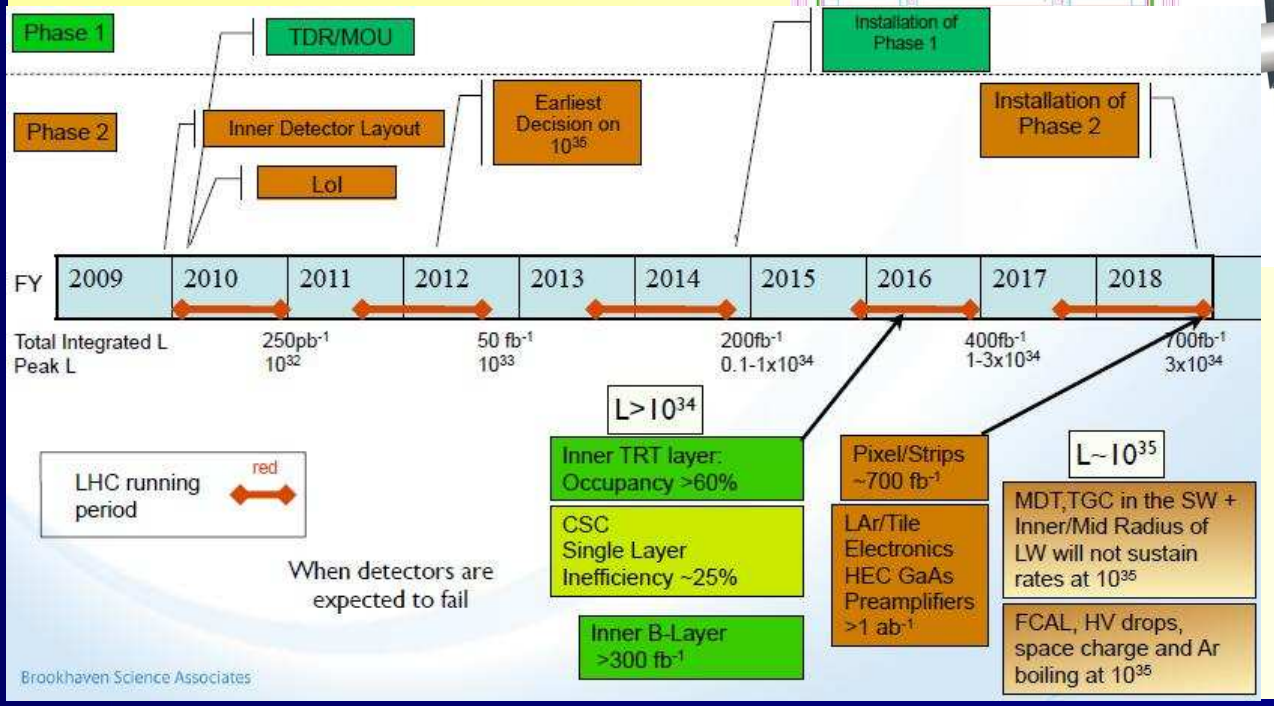
BNL Planned Contributions to the Detector Upgrade

ATLAS will need a major upgrade as integrated luminosity increases

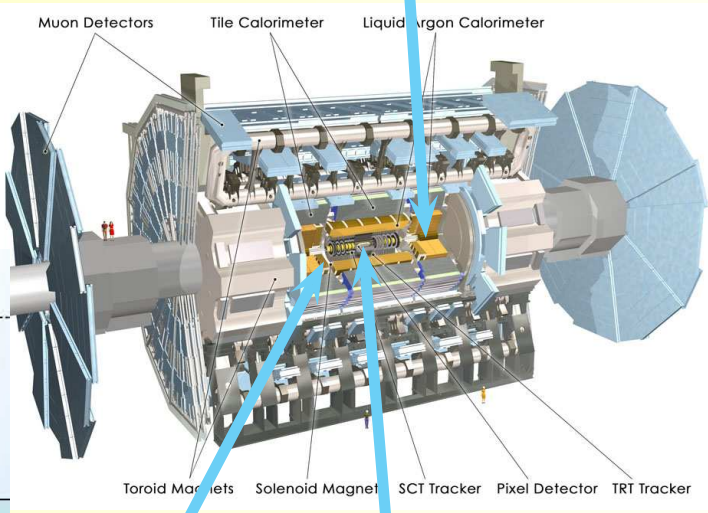
BNL leading three elements of the detector upgrade

study by **Takai**, *et al*





Phase I: augment Forward Muon Spectrometer



Phase II: LAr electronics upgrade

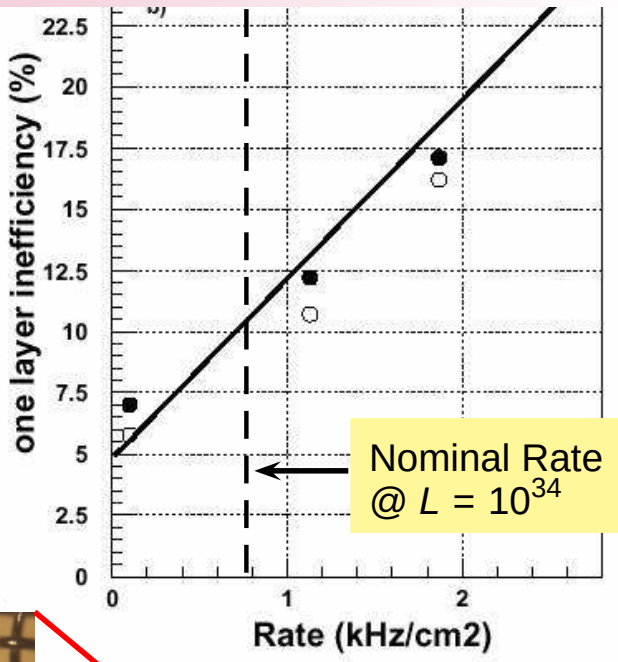
Phase II: silicon staves for Inner Detector replacement

BNL Contributions to Forward Muon Upgrade

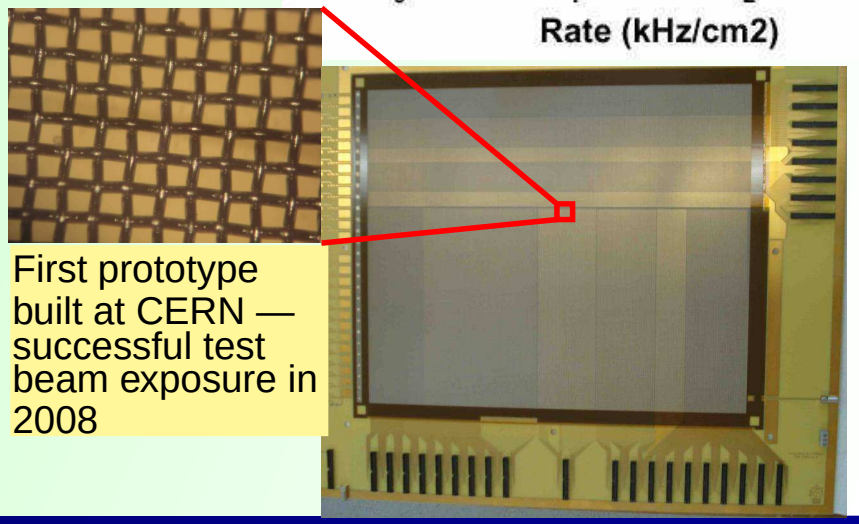
Adams, DeGeronimo, Gordeev, Ikarios, Nikolopoulos, **Polychronakos**, Tcherniatine

- Design of muon detectors and readout driven by cavern background rates:
  - cavern backgrounds could be as much as ×5 higher
- ×3 increase in luminosity makes operation of CSC marginal

- BNL joined CERN–RD51 which streamlines R&D on Micro-Pattern Gas Detectors (GEM and MicroMegas)
- Bulk MicroMegas offer a promising technology for large area, high rate/resolution detectors covering the needs of ATLAS Muon for Phases I & II



- BNL coordinating US ATLAS R&D participation on MicroMegas with:
  - U. of Arizona
  - U. of South Carolina
  - U. of Washington
- **BNL leading development of front-end electronics for forward muon upgrade**



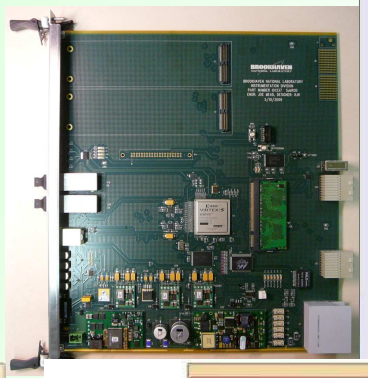
First prototype built at CERN — successful test beam exposure in 2008

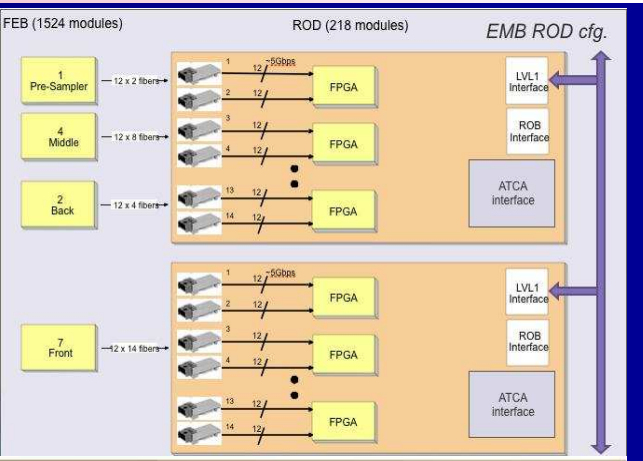
BNL Contributions to LAr Electronics Upgrade

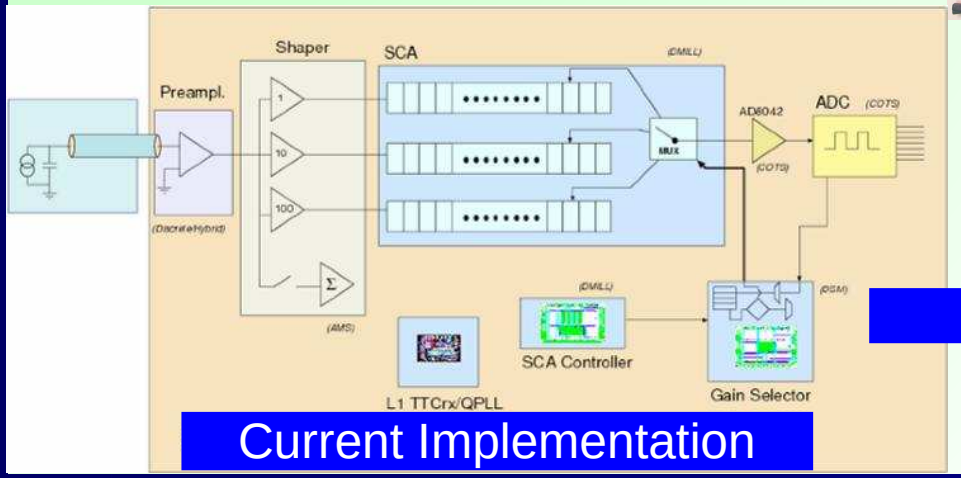
- Current Front-End electronics designed for 10 years @ 10^{34}
  - will not survive much beyond 700 fb^{-1}
- BNL leading effort to define new readout architecture in collaboration with several EU institutions and US universities:
  - Columbia U.
  - U. Pennsylvania
  - Yale U.
  - Southern Method U.
  - U. Arizona

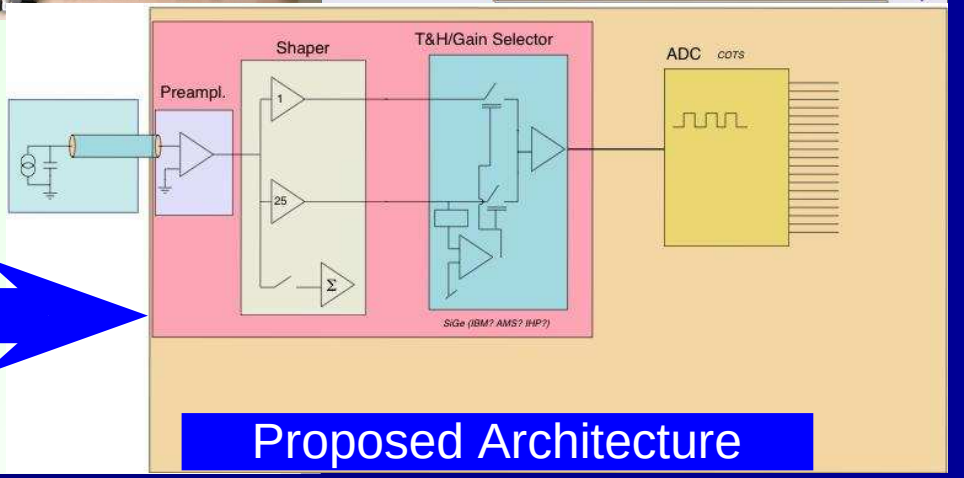
LAr Upgrade Coordinator: ***Lanni***

Chen, **Gadfort**, Kierstead, **Lanni**, Makowiecki, Mead, Radeka, Rescia, **Takai**, Vernon









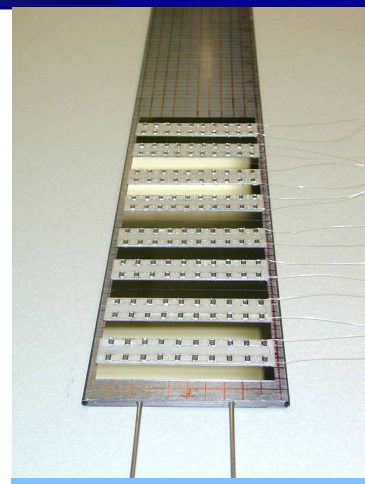
BNL Contributions to Silicon Tracker Upgrade

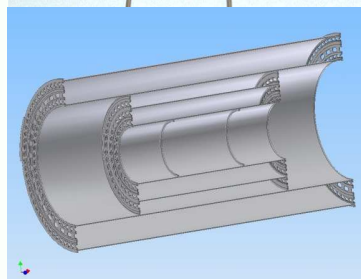
- Current silicon tracker will not survive much beyond 700 fb^{-1}
- Replacement will have 3× the area and 10× the channels

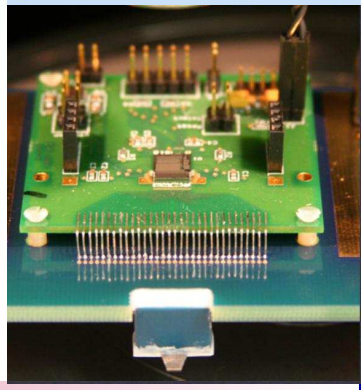
- Additional effort needed for new silicon tracker
  - BNL has experience with a number of silicon detectors (P238 at SPS, E896 at AGS, STAR-SVT at RHIC, PP2PP at RHIC)
  - BNL Instrum. Div. is unique source of expertise in rad. hard Si detectors

- ATLAS adopted several proposals that included BNL contributions
  - US proposal for stave concept (successful collaboration between LBNL, BNL, and US universities)
  - real and slow control protection of serially powered stave
- We are actively engaged in silicon strip R&D
  - leading stave prototyping efforts in US (with LBNL and Yale U.)
  - pioneered a new technique of testing of large sensors (with Stony Brook)
  - developed design for barrel and stave support structures
  - p-type sensor irradiation studies (with New York U.)

- US ATLAS is developing a working model with two main centers
  - pixels at LBNL/SLAC + western universities
  - strips at BNL + eastern universities
  - collaboration LBNL/BNL for common developments







Duffin, **Lynn**, **Pleier**

Staff Increases Proposed at 2009 Proton Research Review

BROOKHAVEN NATIONAL LABORATORY

- add 1 staff scientist and 1 post-doc each year to core program
- increase in funding needed for later years

- Split between physics analysis and detector R&D
  - attract promising young physicists with long-term career paths
- Students
  - share cost with universities
  - close guidance by staff
  - universities value this collaboration

		New Hires				FY12
Staff Scientists	**Current**	**2009**	**2010**	**2011**	**2012**	**Total**
Physics Analysis	4.0	0.5			0.5	5.0
Performance	2.5					2.5
Software	2.5					2.5
Analysis Support	1.0					1.0
LAr	1.5			0.5	0.5	2.5
Muon	0.8		0.5	0.5		1.8
TC	0.2					0.2
Si R&D	1.0	0.5	0.5			2.0
Total Staff:	13.5	1	1	1	1	17.5

Postdocs	**Current**	**2009**	**2010**	**2011**	**2012**	**Total**
Physics Analysis	0.5	0.5	0.5	0.5	0.5	2.5
Performance	0.5					0.5
LAr	1.0	0.5		0.5		2.0
Si			0.5		0.5	1.0
Total Postdocs:	2	1	1	1	1	6

Total Students:	0	2	1	1	–	4

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- add 1 staff scientist and 1 post-doc each year to core program
- increase in funding needed for later years

funded positions

- Split between physics analysis and detector R&D
  - attract promising young physicists with long-term career paths
- Students
  - share cost with universities
  - close guidance by staff
  - universities value this collaboration
    - 2 students from Iowa State U.
    - 1 student from U. Oregon will begin in Oct 2009

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Conclusions

- BNL's contributions to ATLAS are critical to the success of the experiment
  - all BNL deliverables are operational; detector is being commissioned using cosmic-ray muons
  - major contributions in core software and performance
  - we will maintain the current level of commitments to ATLAS detector M&O, software, and performance
- We are eagerly awaiting collision data...
  - leading roles in physics analyses
  - prepared for detector commissioning and early physics possibilities
  - ready for exciting physics discoveries
- ...and working towards the ATLAS upgrade
  - leading efforts in LAr calorimeter, Forward Muon detector, and Silicon Tracker

ATLAS Leadership Roles

- 3 of 7 Physics Working Groups (SUSY, Higgs, Heavy Ion)
- Trigger Coordination
- TC Project Office
- CSC System Manager
- Forward Muon Upgrade
- ZDC System Manager
- LAr Steering Group
- LAr Software & Performance
- LAr Upgrade
- Si Tracker Upgrade

- BNL committed to supporting US ATLAS program
  - largest and most productive Tier 1 in ATLAS
  - Analysis Support Center & Jamborees
  - host laboratory for US ATLAS
- With the proposed modest increase in staff, postdocs, and students, BNL will be able to further strengthen our contributions to ATLAS
  - reap physics discoveries in the LHC era
  - tackle the challenges of sLHC Upgrade
  - support and strengthen US ATLAS physics analysis and detector R&D program